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BY THEIR GRAVITATIONAL RADIATION

by

V. F. Schwartzman
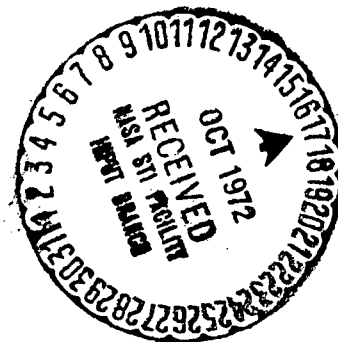
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O vozmozhnom ob'yasnenii sboev perioda pul'sarov ikh
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On the Possible Explanation of Period Breakdowns of Pulsars by their Gravitational Radiation

In 1969 a breakdown of the PSR 0833-45 period has been observed where $\Delta P \simeq -2 \cdot 10^{-6} P_0$, $\Delta \dot{P} \simeq +10^{-2} \dot{P}_0$ [1]. There is only one paper [2] in which a serious attempt has been made to explain both of these facts. It is exactly these facts that are related to the superfluidity of the interior neutron star (NS). Here the phenomenon itself is examined by the authors as a [2] proof of the superfluidity hypothesis. Below we suggest another explanation of the breakdown of the PSR 0833-45, based on the possibility of the pulsars to emit gravitational waves and the fact that as a result of "starquakes" the quadrupole moment of the star must change. Observations conducted during next year will make possible to evaluate the role of each of these effects.

As is known, due to the presence of a magnetic field, the rotating neutron star must be a triaxial ellipsoid and emit gravitational waves [3]; the corresponding drift of the period:

$$\dot{P}_{gr} \equiv \gamma \dot{P}_{obs} = \frac{25}{4} \frac{(2\pi)^4}{P^3} \frac{GI}{c^5} \epsilon^2. \tag{1}$$

Here $I \equiv M(a^2 + b^2)/5$, $\epsilon \equiv (a-b)/b \ll 1$, the magnetic axis is perpendicular to the rotation axis ($\vec{H} \parallel \vec{a} \perp \vec{b}$). The observed drift, $\dot{P}_{obs}$, generally speaking, is greater than the "gravitational," $\dot{P}_{gr}$, $\gamma < 1$, since the electromagnetic mechanisms must also contribute to the braking.

The gradual decrease of the rotation frequency of neutron stars stipulates the decrease of the flatness of the balanced shape; the corresponding changes of the star shape due to the existence of a solid (crystal) crust must occur in jumps [4]. These "starquakes" cannot, however, be strictly axially symmetrical. Actually the break of the crust in one area immediately leads to a decrease of stress in the remaining areas, where for this reason no "recarving" takes place. A specific role must be played also by the pressure anisotropy related to the presence of strong magnetic fields (up to 10^{15} gauss) <u>inside</u> the neutron stars. Finally, it is possible, in our opinion, to expect that the crystal lattice [4] in the magnetic field will not be cubical.

Let us write the change of the length of the ellipsoid axsis after rearrangement as follows:

$$\left. \begin{array}{l} a = a_0(1+\delta_1) \\ b = b_0(1+\delta_2) \end{array} \right\} \quad |\delta_1|, |\delta_2| \ll \epsilon \ll 1. \tag{2}$$

The corresponding change $\delta \dot{P}_{gr}$ (See (1))

$$\delta \dot{P}_{gr} \equiv \Delta \dot{P}_{gr}/\dot{P}_{gr} = \Delta \dot{P}_{obs}/\gamma \dot{P}_{obs} \simeq 2(\delta_1 - \delta_2)/\epsilon. \tag{3}$$

The period jump proportional to the change in the inertia of the solid:

$$\delta P \equiv \Delta P/P \simeq \delta_1 + \delta_2. \tag{4}$$

Designating $\delta_1 - \delta_2 \equiv a(\delta_1 + \delta_2)$ results in:

$$\delta \dot{P}_{obs} = \delta P (2a\gamma^{1/2}\epsilon_o^{-1}). \tag{5}$$

Here $\epsilon_0 \equiv \epsilon\gamma^{1/2}$[*] is the value expressed by P and $\dot{P}_{obs}$ (See (1)). In PSR 0833-45 $P = 0.089$ sec., $\dot{P}_{obs} = 1.25 \cdot 10^{-13}$, i.e., $\epsilon_0 \sim 10^{-3}$. According to [1], $\delta P = -2 \cdot 10^{-6}$, $\delta \dot{P}_{obs} \simeq +10^{-2}$ have been observed; from [5] we see $\{a\gamma^{1/2}| \sim 1; |\delta_1|, |\delta_2| \sim 10^{-6}$.

The observational selection of the hypotheses is simple. If the breakdown parameters are completely stipulated by the superfluidity, the value P must in the course of several years, return to its former value; in addition rapid oscillations of the period must exist [2]. In a "strictly gravitational" model, only stepwise changes of P and $\dot{P}$ are possible (digressing from the secular variation). Here both $\delta P > 0$ and $\delta P < 0$ are possible, which corresponds to the analysis of the pulsar age [6]. Finally with the presence of both effects, derivative $\dot{P}$ will not return to the former value, but to a somewhat different value; to determine the role of the gravitational radiation, it will be necessary

*Copy unclear.

to substitute in (5) the uncomensated in time portion of δP. The breakdown parameters make it possible to measure (estimate from the top) the force of the gravitational radiation of PSR 0833-45!

Recently it has been reported [7] that a pulsar in the Crab NP0532 also suffered a jump, moreover $\delta P = -2 \cdot 10^{-9}$, $|\dot{\delta P}| < 10^{-4}$. If our hypothesis is correct, then according to (5), $|\delta P| \lesssim 10^{-5}$, and the probable value $|\delta P| \sim 10^{-6} - 10^{-7}$.

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Institute of Applied Mathematics of the USSR Academy of Sciences
P. K. Shternberg, State Astronomical Institute
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References

1. P. Reichley, J. Downs, _Nature_ 222, 229, 1969.

2. G. Baym, C. Pethick, D. Pines, M. Ruderman, _Nature_ 224, 872, 1969.

3. I. S. Shklovskij, _Astronomical Journal_ 46, 715, 1969.

4. M. Ruderman, _Nature_ 223, 597, 1969.

5. J. P. Ostriker, J. E. Gunn, ApJ 157, 1395, 1969.

6. I. S. Shklovskij, Astronomical Circular No. 519, 1969.

7. P. E. Boyton, E. J. Groth 111, R. B. Partridge, D. T. Wilkinson, _Circ IAU_ 2179, 1969.